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BEHAVIOUR OF HIGH PERFORMANCE CONCRETE BY USING RECYCLED AGGREGATE ON BEAM UNDER STATIC AND CYCLIC LOADING

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ABSTRACT

Due to the increasing cost and demand for the conventional materials, there is a huge necessity in using alternative materials for the production of concrete. The alternative materials that are used should be reliable as well as eco-friendly. Recycled concrete can be used as an aggregate in structures without affecting the strength and performance of the conventional concrete. The waste concrete removed from RMC plant, construction debris can be recycled. It should be crushed and treated well before using it in the new concrete. Recycled aggregate concrete would save the resource and cost of the project thus, protecting the environment. The ultimate goal of the present experimental studies is to achieve the strength by fully replacing the natural coarse aggregate with recycled aggregate. Further the reinforced concrete beams are made with recycled aggregate concrete with different percentage of steel and its behavior will be studied under static and cyclic loading.

Key words: Conventional concrete; Recycled aggregate concrete; Static load; Cyclic load; Eco-friendly.

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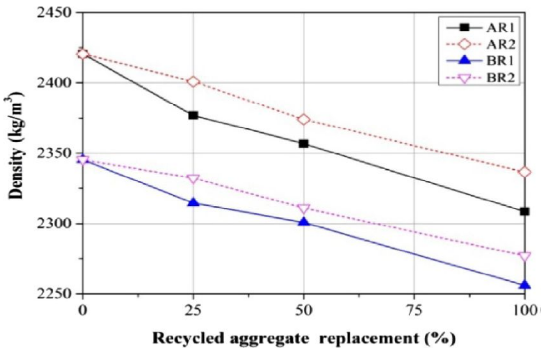
1. INTRODUCTION

Concrete is a durable and versatile construction material, composed of cement or other cementitious materials, aggregate and water. Recycled aggregate concrete (RAC) is the new concrete which is obtained by demolishing the waste and used concrete. Recycle aggregate can be used in place of natural coarse aggregate in the concrete without affecting the strength and performance of the concrete. The recycled aggregate concrete has less specific gravity and high water absorption while compared to the conventional concrete [1]. Hence it should

be tested for strength as well as durability aspects. Many of the researchers had come across with demolishing of concrete. Cimian Zhu (2016) prepared a new type of recycled aggregate, large -size recycled coarse aggregate (LRCA) which is having a maximum size of 80 mm [2]. It is done to simplify the crushing process so that there will be high production efficiency. The result shows that LRCA has good mechanical properties and can be used in mass concreting such as pile foundation platform, foundation support structures etc. [2].

Since, the quality of RAC mainly depends on the quality of parent concrete. The parent concrete is weak and old than the quality of RAC can be improved by various treatment processes like acid treatment, thermal treatment and mechanical treatment etc[3]. Many researchers have ignored the durability performance of recycled concrete. Yiren Zhou (2015) have mainly discussed on the carbonation resistance and freezing and thawing resistance of recycled aggregate concrete. The study shows that RAC has high carbonation depth with increase in replacement ratio of natural coarse aggregate by recycled coarse aggregates in a mix. The Freezing and thawing performance of RAC is lower than concrete of natural aggregate. This is due to high water absorption of recycled aggregate [4].

In recent years, the wastage of concrete is seen to be increased due to the structural removal and demolition, earthquake etc, which has led to the wastage of land and resources. So, recycled aggregate which can be further used in the construction. . A Ministry of the Urban Development of India, circular on June 28, 2012 told the states to set up recycle construction waste plant in all cities which are having population over 10 lakh. The practice of using RAC has started few decades. But it has limited use only in plain cement concrete due to its poor performance in reinforced structural members. The crushed concrete can also be used as fine recycled aggregate. Horward Hwang (2016) has studied the various properties of fine recycled aggregates which are obtained from crushed concrete wastes. Fine recycled aggregate was obtained from crushed waste concrete by two methods. One yields the coarse aggregates as well as fine aggregates (R1) and the second yields only fine aggregates (R2). Later, the concrete mixes were made for both type of recycled aggregate and compared their result [5]. Figure 1.1 shows the density of concrete at 28 days and Figure 1.2 shows the compressive strength of concrete specimens after 28 days.



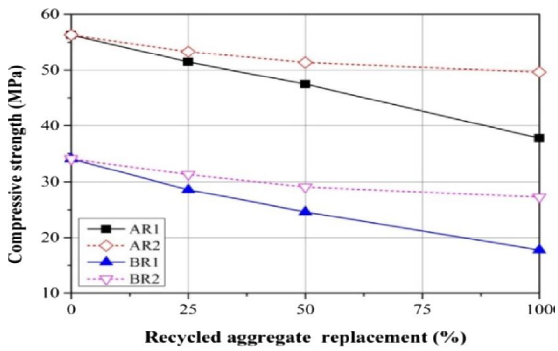


Figure 1.1 Density of concrete at 28 days **Figure 1.2** Compressive strength after 28 days

RAC can effectively resist the low temperature as no spalling of concrete was observed. When it is exposed at high temperature, mass loss increased, because of higher moisture content in RCA. At a temperature of 300^{0}C, the thermal conductivity of RCA concrete has 10-20% lower than normal concrete [6]. Haifeng Yang and Wenwu Lan (2016) have experimentally studied on the bad performance between deformed bars and recycled aggregate concrete (RAC) at elevated temperature. When the temperature is below 400^{0}C[7], the relative bond strength of RAC is sharply decreases whereas when the temperature rises above 500^{0}C, then the bond strength decreases at faster rate[8].

Now a day, RAC can also be used in structural members if we get the proper strength and durability. The poor performance of concrete made with recycled aggregate can be compensated by obtaining the proper mix design with various trial mixes. Since the structural elements are generally subjected to shear forces and bending moment. Reinforcement are provided in both longitudinally and transversely to resist these actions. Bending moment is main cause for the deflection of structural element. If the structural element made with RAC have adequate strength to resist these forces than we can use recycled aggregate concrete in our structural element.

A lot of studies are done regarding the recycled aggregate concrete which can be found in literature. They have focused mainly on the effect of replacement ratio of natural aggregates by recycled aggregates. The ultimate goal of the present experimental studies is to achieve the strength by fully replacing the natural coarse aggregate with recycled aggregate. Further the reinforced concrete beams are made with recycled aggregate concrete and its behavior will be studied under static and cyclic loading. Recycled aggregate concrete would save the resource and cost, thus protecting the environment.

2. MATERIAL DESCRIPTION

2.1. Cement

The cement should be used as per IS specification. Several types of cements are available in the market. Ordinary Portland Cement (OPC) of 53 grade is used during the experiment. Cement has been tested properly before being used and its physical properties are verified by the IS 4031-1988. Physical properties of cement have been shown in below Table 1.

Table 1 Physical properties of cement

S. No.	Description	Experimental Value
1	Fineness modulus	4.49
2	Specific gravity	3.15
3	Initial setting time	31.5 min
4	Standard consistency	32%

2.2. Fine Aggregate

Crushed sand which passes through the 4.75 mm sieve, are taken as fine aggregate. The physical properties of fine aggregate was verified by the IS 383-1970 and listed in below Table 2.

Table 2 Physical properties of fine aggregates

S. No.	Characteristics	Experimental Value
1	Specific gravity	2.60
2	Zone of aggregate	Zone III

2.3. Coarse Aggregates

Crushed aggregate which are large to be retained on 4.75 mm IS sieve are termed as coarse aggregate. The sizes of coarse aggregate that have been used throughout the experimental studies are 10 mm and 20 mm. Dust and dirt were removed from the coarse aggregate by washing and drying its surface. Table 3. shows the physical properties of coarse aggregate.

Table 3 Physical properties of coarse aggregates

S. No.	Description	Experimental value
1	Water absorption	2%
2	Specific gravity	2.95

2.4. Recycled Aggregate

Recycled aggregate can be used as an aggregate in the structures without affecting the strength and performance of the concrete. The concrete recovered from RMC plants, construction debris or laboratory wastes are crushed and treated well before using it in the new concrete. The recycled concrete has less specific gravity and more porosity while compared to the conventional concrete[9]. Hence it should be tested for strength aspects. Recycled aggregate concrete would save the resource and cost, thus protecting the environment. Figure 2. shows the recycled aggregate that have been used during the experiment.

Figure 2 Recycled aggregate

Table 4 Physical properties of Recycled aggregates.

S.No.	Characteristics	Experimental Value
1.	Specific Gravity	2.42
2.	Water Absorption	5.26

2.5. Admixture

Superplasticizer also known as water reducers are used as chemical admixture during the construction work. These are used to increase the workability of the concrete. Ligno Sulphonate is used as chemical admixture whose specific gravity is 1.08. Fly ash is also used as mineral admixture to increase the performance of concrete. The amount of admixture used, are kept constant throughout the experimental work.

2.6. Water

Water is used in the concrete to remove the hydration of cement as well as increases the workability. Fresh and clean water should be used for casting and curing of the specimen. Impurities in water may affect the strength and durability of concrete.

3. EXPERIMENTAL PROCEDURE

Concrete mix design (M40) was designed by IS code method using IS:10262-2009 for both conventional and recycled aggregate concrete.

3.1. Hardened Concrete Tests

Tests on concrete were conducted after attaining its hardened stage. Compressive strength test, Split tensile strength test and Flexural test are done after 7 days, 14 days and 28 days.

3.1.1. Compressive Strength Test

Cubic mould sizes of 150 mm X 150 mm X 150 mm are used to determine compressive strength. Nine cubes for both CC as well as with RAC were casted. Table 5 and Figure 3 show the compressive strength of CC and RAC.

Table 5 Compressive strength of concrete for 7, 14 and 28 days

SPECIMEN TYPE	COMPRESSIVE STRENGTH (MPa)		
	7 days	14 days	28 days
Conventional Concrete	37.87	46.19	54.65
Recycled Aggregate Concrete	33.36	46.18	52.84

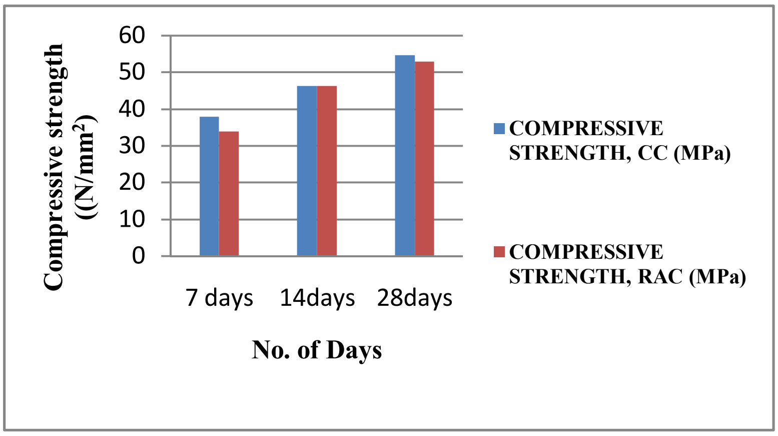


Figure 3 Compressive strength comparison between CC and RAC

3.1.2. Split Tensile Test

Cylindrical mould sizes of 150 mm X 300 mm size concrete cylinder are used to determine the split tensile strength. Nine cylinders for both conventional as well as with RAC were casted. Below Table 6 and Figure 4 shows the split tensile strength of concrete.

Table 6 Tensile strength of concrete for 7, 14 and 28 days

SPECIMEN TYPE	SPLIT TENSILE STRENGTH (MPa)		
	7 days	14 days	28 days
Conventional concrete	2.89	3.27	4.26
Recycled Aggregate Concrete	2.69	3.10	4.05

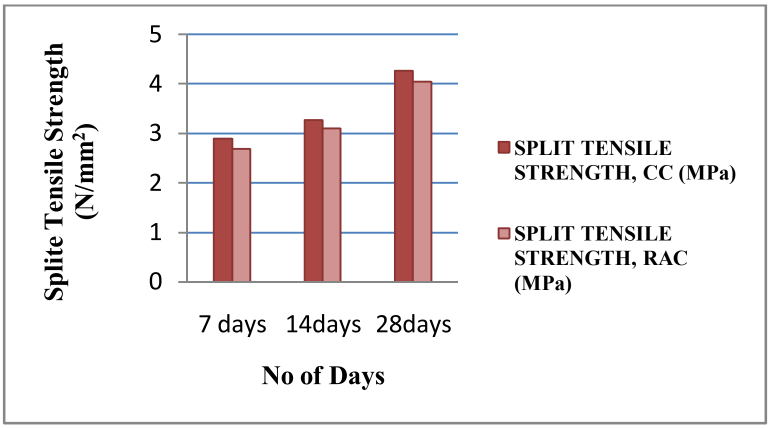


Figure 4 Split tensile strength comparison between CC and RAC for 7, 14 and 28 days

3.1.3. Flexural Test

Beam mould sizes of 100 mm X 100 mm X 500 mm are used to determine the flexure strength. Nine beams for both conventional as well as with RAC were casted[10]. Table 7 and Figure 5 show the flexural strength.

Table 7 Flexure strength of concrete for 7, 14 and 28 days

SPECIMEN TYPE	**FLEXURE TEST (MPa)**		
	7 days	**14 days**	**28 days**
Conventional concrete	5.08	6.33	7.82
Recycled Aggregate Concrete	5.06	6.20	7.62

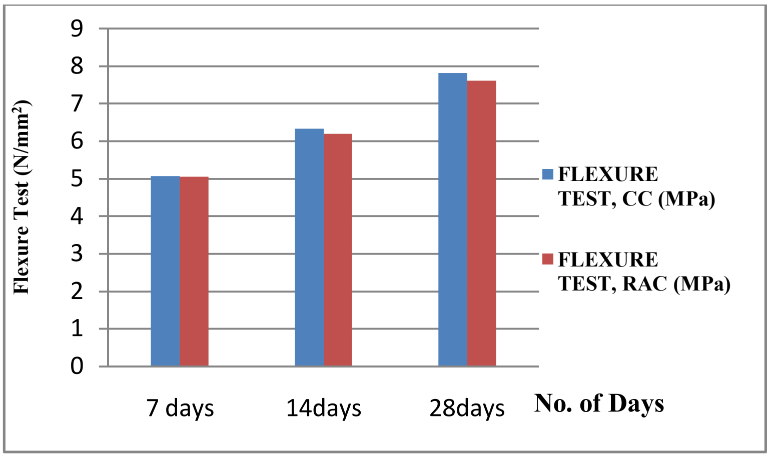


Figure 5 Flexural strength comparison between CC and RAC for 7, 14 and 28 days

3.2. Tests on Beam

Two number of Reinforced concrete beam of size 1500mm x 150mm x 220mm were casted for both CC and RAC. Later, the percentage of the steel in the beam was increased up to 2% for RAC (+) and test were conducted under static and cyclic loading. Figure 6 shows the mould of beam.

Figure 6 Mould of Beam

3.2.1. Static Loading

Beams were subjected under static loading for CC, RAC and RAC (+). Figure 7 shows the setup of the beams under loading. Later the comparison has been done by showing the load vs. deflection graph of various beams on Figure 8. Below Table 8 shows the description of beams under static loading.

Figure 7 Setup of beam under Static loading

Table 8 Comparison of Different Beams under Static Loading

S.NO	Descriptions	CC	RAC	RAC (+)
1	Initial crack	58 kN	47 kN	64 kN
2	Middle crack	86 kN	66 kN	82 kN
3	Ultimate crack	164 kN	140 kN	152 kN
4	Deflection (max)	4.18 mm	6.5 mm	5.2 mm
5	Crack width	2 mm	2.2 mm	2.1 mm

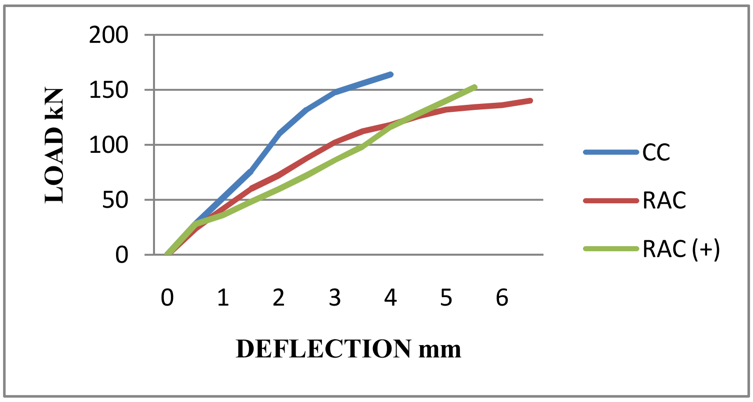


Figure 8 Load vs. Deflection of beam under static loading.

3.2.2. Cyclic Loading

Beams were subjected under cyclic loading for CC, RAC and RAC (+). It was conducted under 4 cyclic loads.

- For the first cycle, the load was limited up to 20 kN and for second cycle the load was limited up to 40 kN. No initial crack was noted under these two cycle loads. Refer Figure 9 and Figure 10 for the first and second cyclic load.
- For third cycle the load was increased up to 80 kN and cracks were observed in all cases. Refer Figure 11 for the third cyclic load.
- For the fourth cycle, the load was increased up to ultimate load. Refer Figure 12. For the fourth cyclic load.

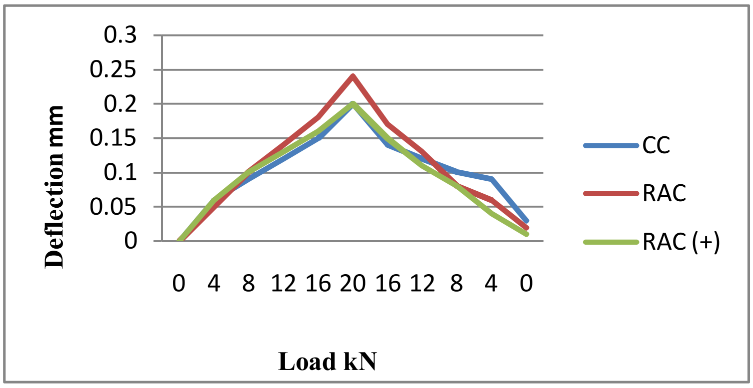


Figure 9 First cyclic load

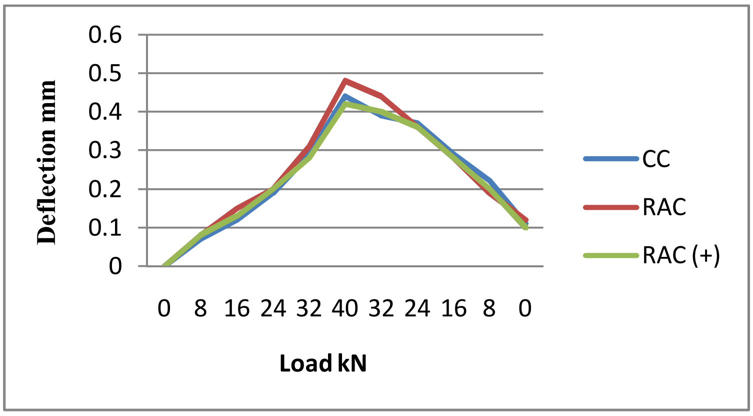


Figure 10 Second cyclic load

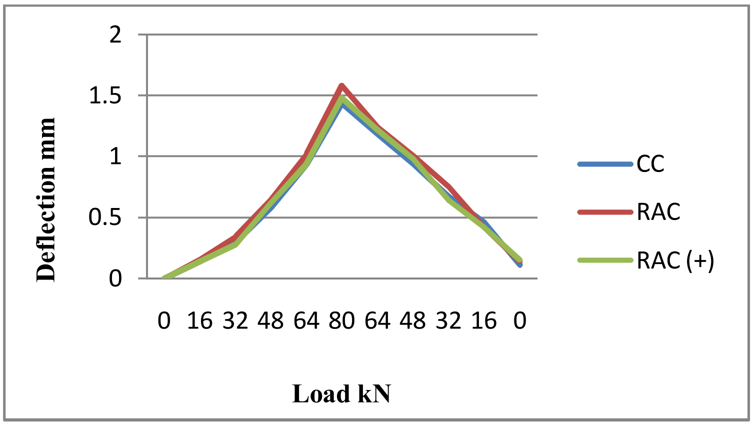


Figure 11 Third cyclic load

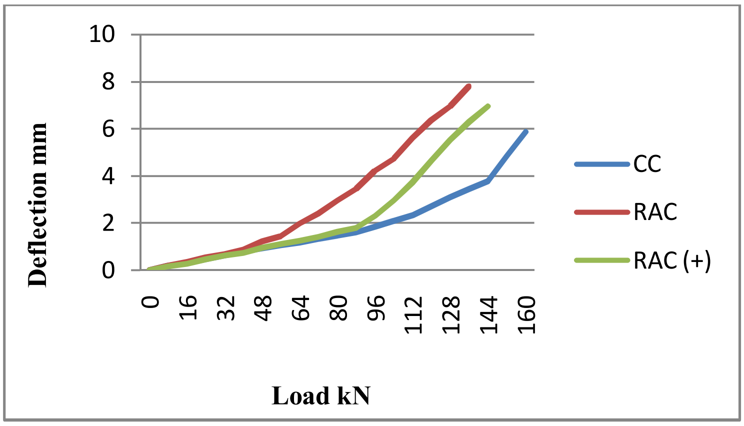


Figure 12 Fourth cyclic load

4. CONCLUSION

This paper investigated the use of recycled aggregate (RA) in our structural element. At first, the desired strength of concrete is obtained by the use of RA and natural aggregate (NA). Later beams were casted and observed under static and cyclic loading. It was observed that beam made with RA has inferior strength than beam made with NA. So to enhance the property of beam made with RA, the percentage of steel was increased up to 2%. Hence, this study draws the various conclusions

- The compressive strength of RAC was decreased by 8% than CC in 28 days.
- Split tensile strength of RAC was decreased by 4.92% than CC in 28 days.
- The Flexural strength of RAC was decreased by 2.55% than CC in 28 days.
- Under static loading, the deflection was maximum of 6.5 mm for RAC. Crack width was also maximum for RAC. The ultimate load was maximum for CC which was 164 kN. RAC has 140 kN as a ultimate load which is 8.53 % lesser than CC. RAC (+) shows more ultimate load than RAC which is quiet acceptable.
- The first and second cyclic loading shows no initial crack. Later the loading was increased in third cyclic load and cracks were observed in all three cases. In fourth cyclic load, the ultimate load was observed which was maximum for CC. RAC has 8.5 % lesser ultimate load than CC. Deflection was also maximum for RAC, which was 7.8 mm. RAC (+) has more ultimate load and lesser deflection than RAC.

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